LEVEL II

MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

AD A106453

ARNAULT BRANCH MINE DAM
WASHINGTON COUNTY, MISSOURI
MO 30716

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

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This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO ATTENTION OF

SUBJECT: Arnault Branch Mine Dam (MO 30716) Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Arnault Branch Mine Dam (MO 30716).

It was prepared under the National Program of Inspection on Non-Federal Dams.

This dam has been classified as unsafe, emergency by the St Louis District as a result of the application of the following criteria:

a. Spillway will not pass 10-year frequency flood without overtopping of the dam. The spillway is, therefore, considered to be unusually small and seriously inadequate.

b. Overtopping could result in dam failure.

c. Dam failure significantly increases the hazard to life and property downstream.

SIGNED

SUBMITTED BY: _____ 26 NOV 1980
Chief, Engineering Division — Date

APPROVED BY: _____ 1 DEC 1980
Colonel, CE, District Engineer — Date

ARNAULT BRANCH MINE DAM

Washington County, Missouri

Missouri Inventory No. 30716

Phase I Inspection Report

National Dam Safety Program.

Arnault Branch Mine Dam (MO 30716),
Mississippi - Kaskaskia - St. Louis Basin.
Washington County, Missouri. Phase I
Inspection Report.

Prepared by

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(15) DACW 43-80-C-0066

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Under Direction of

St Louis District, Corps of Engineers

(12)

for

Governor of Missouri

(11) Sep[redacted]80

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Arnault Branch Mine Dam
State Located	Missouri
County Located	Washington
Stream	Unnamed Tributary of Arnault Creek
Date of Inspection	24 June 1980

The Arnault Branch Mine Dam (Mononame 555), Missouri Inventory Number 30716 was inspected by Mr L. M. Krazynski (geotechnical engineer), Mr R. Juyal (hydrologist), and Mr J. B. Stevens (geotechnical engineer). It is an abandoned tailings dam.

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, US Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. They are intended to provide an expeditious identification, based on available data and a visual inspection, of those dams which may pose hazards to human life or property. In view of the limited scope of the study, no assurance can be given that all deficiencies have been identified.

This dam is classified as intermediate in size due to its maximum height of 45 ft. Its storage capacity is 540 ac-ft. The intermediate size classification applies to dams with heights between 40 and 100 ft, or storage capacity between 1000 and 50,000 ac-ft.

The St Louis District, Corps of Engineers (SLD), has classified this dam as a high hazard dam; we concur with this classification. Within the estimated damage zone are four occupied structures. The zone, as determined by the St Louis District, extends approximately four miles downstream.

Our inspection and evaluation indicate that the dam is in poor condition. Specific deficiencies that were noted are insufficient spillway capacity, very steep downstream slope, passage of spillway outflow along the toe of the embankment composed of materials with high erodibility characteristics and the lack of periodic inspections and maintenance. Also deemed as a deficiency is the lack of any stability or seepage analyses.

Hydrologic/Hydraulic studies indicate that a 10 percent probability-of-occurrence event (10-yr flood) will cause overtopping of the dam. These analyses also indicate that the dam will be overtopped for a hydrologic event which produces greater than eight percent of the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

As remedial measures for the Arnault Branch Mine Dam, it is recommended that an additional study be conducted to evaluate, as a minimum, measures to increase the spillway capacity and to reduce the risk of embankment erosion along the present alignment of the discharge channel. The steepness and the high potential for erosion of the existing dam embankment should be taken into consideration in this study. The objectives of the study would be to determine and provide the appropriate spillway location and capacity to decrease the potential for overtopping and to diminish the potential for embankment erosion.

It is also recommended that seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" be performed.

These remedial measures should be performed immediately.

It is further recommended that a program of periodic inspections be implemented without undue delay. The program should include, but not be limited to:

1. Inspection of seepage areas to identify increases in quantity of flow or turbidity of water that might lead to a decrease in the safety of the dam.

2. Inspection of the slopes to identify evidence of slope instability such as cracking, slumping or excessive settling of the embankment. The slopes should also be kept free of harmful vegetation such as large trees. Removal of large trees should be done under the guidance of an engineer experienced in the design and construction of dams. Indiscriminate clearing of large trees could jeopardize the safety of the dam.

Records should be kept of the inspections and any recommended maintenance. The inspections and maintenance should be done under the guidance of an engineer experienced in the design and construction of dams.

WOODWARD-CLYDE CONSULTANTS

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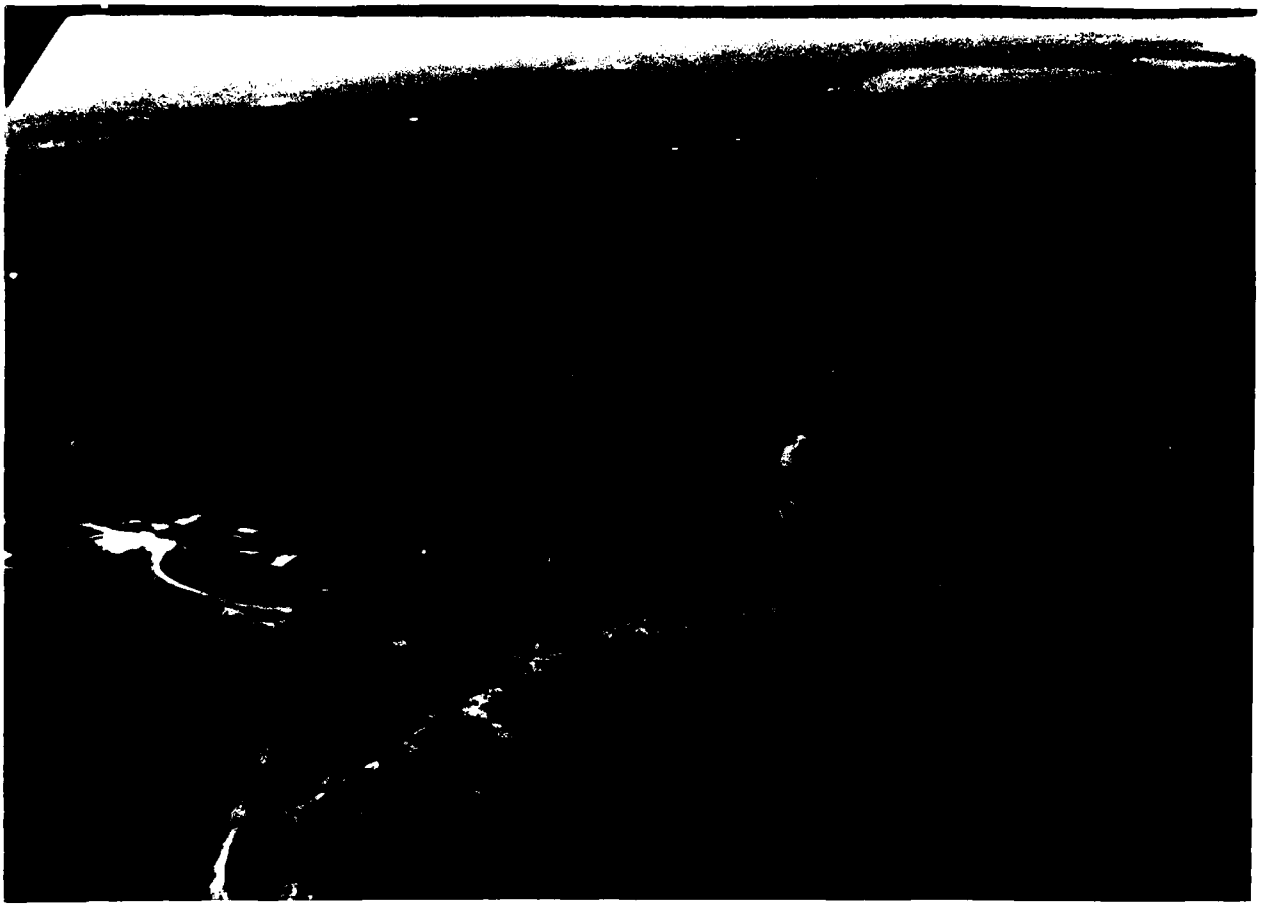

OVERVIEW

ARNAULT BRANCH MINE DAM

MISSOURI INVENTORY NO. 30716

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
ARNAULT BRANCH MINE DAM, MISSOURI INVENTORY NO. 30716
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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
ARNAULT BRANCH MINE DAM, MISSOURI INVENTORY No. 30716

SECTION 1
PROJECT INFORMATION

1.1 General

a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of Arnault Branch Mine Dam (Mononame 555), Missouri Inventory Number 30716.

b. **Purpose of inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted" (Chapter 3, "Recommended Guidelines for Safety Inspection of Dams").

c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams", Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188, "Engineering and Design National Program for Inspection of Non-Federal Dams", prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams", prepared by the St Louis District, Corps of Engineers (SLD). These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 Description of Project

a. **Description of dam and appurtenances.** Arnault Branch Mine Dam is an abandoned tailings dam. Although its construction and usage is typical of other barite tailings dams in the area, it is atypical of dams constructed for the impoundment of water. The unique nature of these tailings dams has a significant impact on their evaluation. A brief description of their construction and usage is necessary to highlight the differences between this tailings dam and conventional water-retaining dams.

At the start of a barite mining operation in this area, a 10 to 20 ft high starter dam is usually first constructed across a natural stream channel. Generally the streams are intermittent so that construction is carried out in the dry. Trees and other vegetation are removed from the dam site and then a cutoff is often made to shallow bedrock. Locally obtained earth, usually a gravelly clay, is then placed to form the embankment. Compaction is limited to that provided by the equipment.

The barite ore is contained within the residual gravelly clay which is mined with earth-moving equipment. At the processing plant, the ore is washed to loosen and remove the soil. This water is obtained from the reservoir area behind the dam. The soil-laden, wash water and water from other steps in the process is then discharged into the reservoir. There the soil is deposited by sedimentation and the water recycled. Another step in the process removes the broken gravel-sized waste which is called "chat".

As the level of the fine tailings increases, the dam is raised. The usual method is to place, by dumping, chat on the dam crest. Then the chat is spread over the crest so that a relatively constant crest width is maintained as the dam is raised. Generally the crest centerline location is also maintained. However, the crest centerline location may migrate upstream if there is insufficient chat available and downstream if an excessive quantity of chat is available. The latter is uncommon, because it is indicative of a poor ore deposit.

This method of construction results in slopes which are close to the natural angle of repose for the chat. They can be considered to be near a state of incipient failure.

A large quantity of water is required for a processing operation, on the order of 2000 to 5000 gal/min. Thus it has been the operators' practice to construct the dam so that all inflow to the reservoir is recycled in order to have sufficient water for the operation. The result is that formal spillways or regulating outlets are generally not constructed. In most cases a low point on or near the dam is provided, should the storage capacity be exceeded.

The fine tailings typically fill more than 80 percent of the total storage volume. This results from the operator's practice of maintaining only a 2 to 5 ft elevation differential between the level of the tailings and the dam crest. The differential is usually greater further away from the discharge point and also typically further away from the dam.

The geotechnical characteristics of the fine tailings are somewhat similar to recent lacustrine clay deposits. Where the tailings have been continuously submerged, they have a very soft consistency and high water contents. When evaporation causes the water level to recede and the tailings are exposed, a stiff crust forms as the tailings dry out. Below the crust, the tailings retain their soft consistency for long periods of time. The consistency is very gradually modified by a slow process of consolidation.

The configuration of Arnault Branch Mine Dam differs from most tailings dams. It consists of the dam proper across the natural stream and a dike starting at the west end of the dam and extending upstream to the spillway. The spillway discharge channel passes along the toe of the dike, past the west end of the dam and into the natural drainage channel.

Otherwise the dam is representative of barite tailings dams. The embankment is composed of chat. The downstream slope is very steep and the upstream slope is covered by the fine tailings. There are no regulating outlets other than the ungated earth-lined spillway.

b. **Location.** The dam is on an unnamed tributary of Arnault Creek and about 3.2 mi W of Old Mines, Washington County, Missouri. It is located in Sec 16, T38N, R2E, about 0.8 mi E from Missouri Hwy F, and is shown on the USGS Richwoods SE 7.5-minute quadrangle map.

c. **Size classification.** The dam is classified as intermediate due to its 45-ft height. The storage capacity is approximately 540 ac-ft. Intermediate dams are those between 40 and 100-ft in height, or those with a storage capacity between 1000 and 50,000 ac-ft.

d. **Hazard classification.** The SLD has classified this dam as a high hazard dam; we concur with this classification. The SLD estimated damage zone extends approximately 4 mi downstream. Located within this zone are four occupied structures.

e. **Ownership.** The dam is reportedly owned by Charles Pfizer & Co, 2001 Lynch Ave, East St Louis, Illinois 62201. Correspondence should be addressed to the attention of Mr William A. Wilkenson, Plant Manager.

f. **Purpose of dam.** The dam was constructed to impound fine barite tailings and the process water. It is currently abandoned.

g. **Design and construction history.** The present owner does not have any documents of the design or construction of the dam. According to Mr Bob Griffey, who managed the mining operation for Pfizer, construction of the dam began in 1970 or 1971 and the site was abandoned in February of 1975. The earth starter dam was built to approximately 30 ft in height and slopes of about 1.5(H) to 1(V). The starter dam is reported to have a clay key to bedrock, which is approximately 5 ft below the residual soil surface. The width of the key was estimated as 10 to 12 ft, as the construction was done using a bulldozer with a blade of approximately this width.

The dam crest was raised by dumping chat primarily on the downstream slope and on the crest. The centerline of the starter dam is on the upstream side of the completed tailings dam. The chat portion of the upstream face was reportedly covered with fine-grained tailings dragged from the reservoir. This created a low permeability seal that reduced seepage of the ponded water.

Mr Griffey also stated that the dam was not overtopped during the time period the mine was in operation.

h. **Normal operating procedures.** At the present time, mining activities have ceased so there are no operating procedures in effect.

1.3 Pertinent Data

a. **Drainage area.** Approximately 0.85 mi^2

b. **Discharge at damsite.**

Maximum known flood at damsite	Unknown
Warm water outlet at pool elevation	N/A
Diversion tunnel low pool outlet at pool elevation	N/A
Diversion tunnel outlet at pool elevation	N/A
Gated spillway capacity at pool elevation	N/A
Gated spillway capacity at maximum pool elevation	N/A
Ungated spillway capacity at maximum pool elevation	115 ft^3/sec at el 843.0
Total spillway capacity at maximum pool elevation	115 ft^3/sec at el 843.0

c. **Elevation (ft above MSL).**

Top of dam	843.0 to 848.0
Maximum pool-design surcharge	N/A
Full flood control pool	N/A
Recreation pool	N/A
Spillway crest (gated)	N/A
Upstream portal invert diversion tunnel	N/A
Downstream portal invert diversion tunnel	N/A
Streambed at centerline of dam	Unknown
Maximum tailwater	N/A
Toe of dam at maximum section	801.5

d. **Reservoir.**

Length of maximum pool	3300 ft
Length of recreation pool	N/A
Length of flood control pool	N/A

e. **Storage (acre-feet).**

Recreation pool	N/A
Flood control pool	N/A
Design surcharge	N/A
Top of dam	530

f. **Reservoir surface (acres).**

Top of dam	41
Maximum pool	41
Flood-control pool	N/A
Recreation pool	N/A
Spillway crest	34

g. **Dam.**

Type	Tailings
Length	1840 ft including dike; 750 ft main dam
Height	45 ft
Top width	25 to 50 ft
Side slopes	D/S, 1.7 (H) to 1(V); U/S, unknown
Zoning	Unknown (probably none)
Impervious core	Unknown (probably none)
Cutoff	Unknown (probably one to shallow rock)
Grout curtain	Unknown (probably none)

h. **Diversion and regulating tunnel.**

Type	N/A
Length	N/A
Closure	N/A
Access	N/A
Regulating facilities	N/A

i. **Spillway.**

Type	Uncontrolled, unlined earth, approximately trapezoidal in shape
Length of weir	N/A
Crest elevation	840.1 ft
Gates	N/A
U/S channel	N/A
D/S channel	Unlined earth

j. **Regulating outlets.** None

SECTION 2
ENGINEERING DATA

2.1 Design

No design drawings or data were found.

2.2 Construction

No construction records or data were found.

2.3 Operation

No records were found for reservoir water elevation or spillway discharge history. The dam is presently abandoned.

2.4 Evaluation

a. **Availability.** There was no data available for review.

b. **Adequacy.** Insufficient data were available to determine the adequacy of the design.

Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not on record, which is a deficiency. These analyses should be performed by an engineer experienced in the design and construction of dams. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. **Validity.** Not applicable.

2.5 Project Geology

The dam site lies on the northern flank of the Ozark structural dome. The regional dip is to the north. The bedrock in the area is mapped as Cambrian age, Eminence and Potosi dolomite formations on the Geologic Map of Missouri (Fig. 4). The Potosi Formation is a light gray medium- to fine-grained dolomite which typically contains an abundance of quartz druse characteristic of chert bearing formations. The Eminence Formation is similar in appearance and conformably overlies the Potosi Formation, but contains less quartz and chert.

The soil at the dam site is a dark red-brown, plastic, stoney residual clay (CH), characteristically developed on the Potosi Formation. It is locally overlain by a 1 to 5 ft thick silty loess (ML). The area is mapped on the Missouri General Soils Map as Union-Goss-Gasconade-Peridge Association.

The Aptus Fault is located approximately 1.5 mi west of the site. The fault is mapped on the Structural Features Map of Missouri as approximately 15 mi in length, trending northwest-southeast. The fault is mapped as northeast side up. The Aptus Fault is mapped within Precambrian and Paleozoic formations and is likely Paleozoic in age. The fault is not considered to be located in a seismically active area, and is not considered to pose a significant hazard to the dam.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. **General.** Arnault Branch Mine Dam was inspected on 24 June 1980, without an owner's representative present.

b. **Dam.** The dam is composed of coarse tailings or "chat". The material (gravel, sandy gravel and sand with some boulders; GW, SW) is cohesionless and permeable and would likely be severely eroded if the dam were overtopped by a significant depth of overflow and/or a long period of time.

The downstream slope is 1.7(H) to 1(V), which is near the natural angle of repose for the chat. Some trees and brush are growing near and on the dam toe. Most of the upstream slope is covered by the fine-grained tailings. The portion of the upstream slope that is above the fine-grained tailings is partially covered by grass and brush and the remainder is covered by gravel-sized chat. The erosion potential of both the upstream and downstream slopes is high to moderate, if they are exposed to flow velocities of over 5 ft/sec.

The vertical and horizontal alignment of the dam crest do not appear to be disturbed by deformation. No evidence of detrimental settlement, depressions, cracking or animal burrows were found during the inspection. It must be emphasized, however, that in the general vicinity of the maximum section on this dam, the surface of the dam was unusually uneven possibly due to lax construction control, as compared to most tailings dams in this area. This resulted in a very irregular downstream slope where possible post-construction deformations would be very difficult to detect (Photo 3; Appendix A).

Dumping of "chat" into irregular piles along both edges of the dam crest has disrupted crest drainage and has created the possibility of local crest erosion and consequent reduction in effective dam height (Photo 1; Appendix A).

Clear seepage was noted from several locations along the toe of the dam and at one location about 25 ft up the slope from the toe (Photos 5 and 6; Appendix A). Seepage quantities at each location ranged from about 1 to 5 gal/min. At the time of inspection, erosion or piping did not appear to be taking place. This was evidenced by the lack of observed suspended sediment in the seepage. Some of the seepage may be due to consolidation of the fine-grained tailings which is beneficial to dam safety. The quantitative effect of seepage on slope stability is beyond the scope of this Phase I report.

c. **Appurtenant structures.** The spillway is a natural earth channel at the south end of the dike. At the entrance, cattails and other brush retard the flow. The soil appears to be moderately erodible.

d. **Reservoir area.** Approximately 65 percent of the reservoir area was above the water level at the time of inspection. The bottom of the reservoir is covered by fine tailings which are relatively impervious. Slopes surrounding in the reservoir area are relatively flat and showed no signs of instability at the time of the visual inspection.

e. **Downstream channel.** The downstream channel is earth-lined and the chat dike forms the east bank (See Fig. A-1 and Photo 4). The channel is roughly trapezoidal in cross-section. Downward erosion is controlled by shallow rock outcrops. However, there is high potential for erosion laterally into the chat dike. During periods of heavy flow this may result in a breach in the dike, which may in turn endanger the main body of the dam. Beyond the north end of the dam the discharge channel enters the natural drainage channel. There are no obstructions which would reduce its capacity below that of the present spillway.

3.2 **Evaluation.** The downstream slope is very steep and although no slides were observed, the slopes are considered to be close to incipient failure.

The high erodibility of the chat indicates that failure would be relatively rapid in the event of significant overtopping. Also, high spillway outflows along the dike and west end of the dam could cause undercutting along the toe of the dam and result in slope failures. This condition should be evaluated by further studies.

The seepage observed in the dam does not appear to be hazardous at this time. It should be periodically checked, however, to detect changes in the amount or turbidity of flow.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

So far as could be determined there are no operational procedures for this dam. The water level is controlled by the crest of the spillway.

4.2 Maintenance of Dam

No records of maintenance on this facility were available.

4.3 Maintenance of Operating Facilities

There are no operating facilities at this dam.

4.4 Descriptions of Any Warning System in Effect

The inspection did not identify any warning system in effect at this facility.

4.5 Evaluation

There are apparently no maintenance or operational procedures in effect. The lack of regular maintenance and periodic inspection is considered a deficiency.

The feasibility of a practical warning system should be evaluated to alert downstream residents should potentially hazardous conditions develop during periods of heavy precipitation.

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. **Design data.** No hydrologic or hydraulic information was available for evaluation of the dam. Pertinent dimensions of the dam and reservoir were surveyed on 17 June 1980, measured during the field inspection or estimated from topographic mapping. The map used in the analysis was an advance print of the USGS Richwoods SE 7.5-minute quadrangle map.

b. **Experience data.** No recorded history of rainfall, runoff, discharge or pool stage data were available for this reservoir or watershed. No evidence of overtopping was observed. Mr Bob Griffey, a former mine employee, stated that the dam had not been overtopped during the period the mine was operating.

c. **Visual observations.**

1. Watershed. The watershed is rural, forested with hardwoods and softwoods predominantly of oak, hickory, pine and cedar. The area of the reservoir is approximately 7 percent of the total watershed area of 0.85 mi^2.

2. Reservoir. The reservoir and dam are best described by the maps and photographs enclosed herewith. The reservoir is partially filled with tailings and the proportions of water to mine tailings has not been accurately determined. The level of tailings storage as observed during the dam inspection, was approximately at the crest of the spillway located at the end of the dike embankment.

3. Spillway. The spillway at the end of the dam embankment is constructed in residual soils at the south end of the western dike. The spillway crest is level with the discharge channel bottom.

4. Seepage. The magnitude of seepage through this dam is not hydrologically significant to the overtopping potential.

d. **Overtopping potential.** The hydrologic/hydraulic analyses indicate that the dam will be overtopped for the 10 percent probability-of-occurrence event. These analyses also indicate that the dam will be overtopped for a hydrologic event which produces greater than eight percent of the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The following table presents the expected severity of overtopping for various percentages of the PMF:

Percent PMF	Maximum Reservoir W.S. Elev. ft (MSL)	Maximum Depth over Dam, ft	Maximum Outflow, ft^3/sec	Duration of Overtopping, hrs
8	842.8	0	89	0
50	844.4	1.4	2500	10.8
100	845.0	2.0	5111	16.3

The maximum discharge for the spillway is 115 ft^3/sec, with water surface taken at the top of the low point on the dike, i.e. elevation 843.0.

The soil at the spillway is considered to be moderately erodible. Erosion of the spillway and downstream discharge channel are expected to be considerable for flows of more than 5 ft/sec. As the embankment material is considered to be highly erodible, overtopping would erode the toe of the western dike and the northwestern end of the main body of the dam. This could lead to failure of the dam.

A more detailed hydrologic study should be conducted to evaluate the location and flow capacities of both the spillway and the discharge channel. The effects of the erosion of the dam, spillway and discharge channel should be included in this study.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. **Visual observations.** The visual inspection of Arnault Branch Mine Dam revealed no evidence of horizontal or vertical displacement of the dam crest alignment. Cracking, detrimental settlement, slides, depressions or other signs of instability were not observed.

b. **Design and construction data.** No design or construction data relating to the stability of the dam were available. Information was obtained on the construction history of the dam from Mr Bob Griffey who managed the mining operation for Pfizer (see Section 1.2g).

c. **Operating records.** No operating records were available.

d. **Post construction changes.** The lack of drawings or construction reports precludes identification of post construction changes. However, no obvious changes were observed. As described in Section 3, the downstream slope of this dam is uncharacteristically non-uniform, compared to most barite tailings dams in this area.

e. **Seismic stability.** The dam is in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analysis is available for review, the seismic stability cannot be evaluated. However, as the tailings are fine-grained, saturated materials and the embankment consists of loose, granular material, it is expected that substantial deformation or failure of the embankment could occur in the event of a severe seismic event.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

a. **Safety.** Based on the visual inspection, the Arnault Branch Mine Dam is judged to be in poor condition. The inadequate spillway capacity, very steep downstream slope, lack of maintenance, high erodibility of the embankment and discharge channel materials, and lack of periodic inspections are the primary reasons for this judgment. Seepage and stability analyses as required by the "Recommended Guidelines for Safety Inspections of Dams" are not on record, which is considered a deficiency.

As a consequence of the widely-used construction procedure, the downstream slopes of the tailings dams are placed at the angle of natural repose for the "chat" material at any given operation. This results in slopes that are very steep and exist in a state close to incipient failure with safety factors close to one. The stability of the embankment is subject to some gradual improvement with time as consolidation and desiccation of the fine-grained tailings results in an increase in strength, and a reduction in lateral pressures on the embankment. The amount of strength gain and increase in stability of the dam cannot be determined without performing tests and stability analyses. For the purpose of this Phase I report it has been recognized that the consolidation of the tailings occurs over a long period of time and the tailings may flow in the event of dam failure.

The slopes placed at angle of natural repose will only remain stable, if they are protected against potential harmful changes, among which are:

1. Overtopping by water

2. Higher pore pressures (or seepage forces)

3. Undercutting of the toe of the slope by erosion or mining activity

4. Increase in the height of the slope

5. Harmful effects of vegetation (particularly tree roots)

6. Liquefaction (such as may result from a seismic event).

The first five changes are subject to control by owners and operators and must receive careful attention in order to maintain stable and safe dam embankments. The sixth influence represents a risk the magnitude of which is not well understood without further study.

b. **Adequacy of information.** The visual inspection provided a reasonable base of information for the conclusions and recommendations presented in the Phase I report. The lack of stability and seepage analyses for the dam as recommended in the guidelines precludes an evaluation of the structural and seismic stability of the dam, which is a deficiency.

c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective action should be initiated immediately, as described in Section 7.2b.

d. **Necessity for Phase II.** In accordance with the "Recommended Guidelines for Safety Inspections of Dams", the subject investigation was a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed immediately are described in Section 7.2b. It is our understanding from discussions with the St Louis District that any additional investigations are the responsibility of the owner.

7.2 Remedial Measures

a. **Alternatives.** There are several general options which may be considered to reduce the possibility of dam failure or to diminish the harmful consequences of such a failure. Some of these options are:

1. Remove the dam, or breach it to prevent storage of water.

2. Increase the height of dam and/or spillway size to pass the probable maximum flood without overtopping the dam.

3. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy.

4. Enhance the stability of the dam to permit overtopping by the probable maximum flood without failure.

5. Provide a highly reliable flood warning system (generally does not prevent damage but diminishes chances for loss of life).

b. **Recommendations.** Based on our inspection of Arnault Branch Mine Dam, it is recommended that further study be conducted to evaluate, as a minimum, the locations and capacities of both the spillway and the discharge channel. The steepness and the high potential for erosion of the existing dam embankment should be taken into consideration in this study. The objectives of the study would be to determine and provide the appropriate spillway capacity to decrease the potential for overtopping, and to diminish the potential for embankment erosion.

It is also recommended that seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" be performed. This study should evaluate the flow susceptibility of the fine-grained tailings. All remedial measures should be performed under the guidance of an engineer experienced in the design and construction of dams.

c. **O & M procedures.** A program of periodic inspections is recommended for Arnault Branch Mine dam. The purpose of the inspection program should be to identify and recommend necessary maintenance. The program should include, but not be limited to:

1. Inspection of seepage areas to identify increases in quantity or turbidity of flow that might lead to a decrease in the safety of the dam.

2. Inspection of the slopes to identify evidence of slope instability such as cracking, slumping or excessive settling of the embankment. The slopes should

also be kept free of harmful vegetation such as large trees. Removal of large trees should be done under the guidance of an engineer experienced in the design and construction of dams. Indiscriminate clearing of large trees could jeopardize the safety of the dam.

Records should be kept of the inspections and any recommended maintenance. The inspections and maintenance should be done under the guidance of an engineer experienced in the design and construction of dams.

REFERENCES

Allgood, Ferris P., and Persinger, Ivan, D., 1979, "Missouri General Soil Map and Soil Association Descriptions," US Department of Agriculture, Soil Conservation Service and Missouri Agricultural Experiment Station.

Department of the Army, Office of the Chief of Engineers, 1977, EC 1110-2-188, "National Program of Inspection of Non-Federal Dams".

Department of the Army, Office of the Chief of Engineers, 1979, ER 1110-2-106, "National Program of Inspection of Non-Federal Dams".

Hydrologic Engineering Center, US Army Corps of Engineers, 1978, "Flood Hydrograph Package (HEC-1) Users Manual for Dam Safety Investigations".

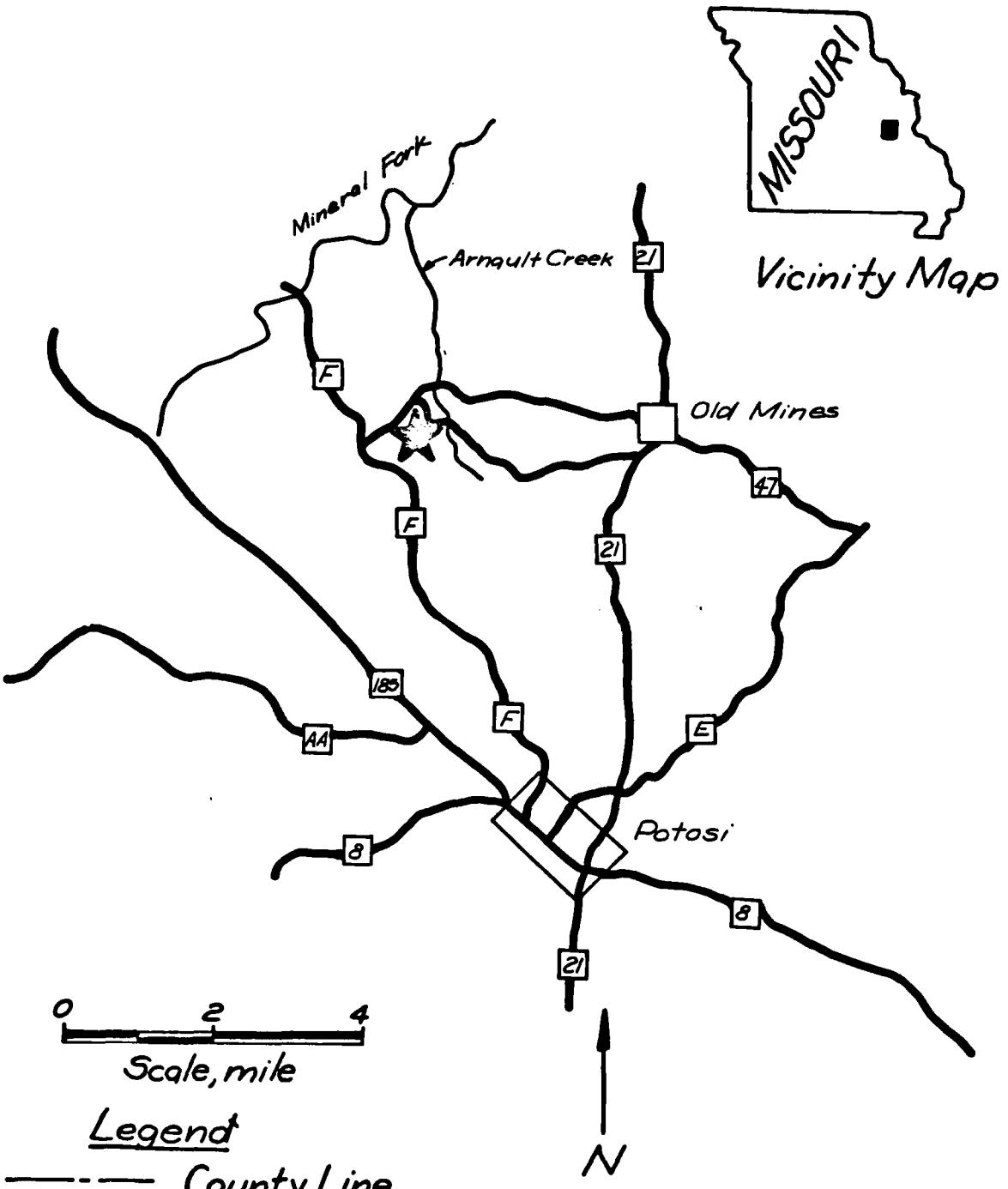
McCracken, Mary H., 1971, Structural Features Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

Missouri Geological Survey, 1979, Geologic Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

St Louis District, US Army Corps of Engineers, 1979, "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams".

US Department of Commerce, US Weather Bureau, 1956, "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 Hours," Hydrometeorological Report No. 33.

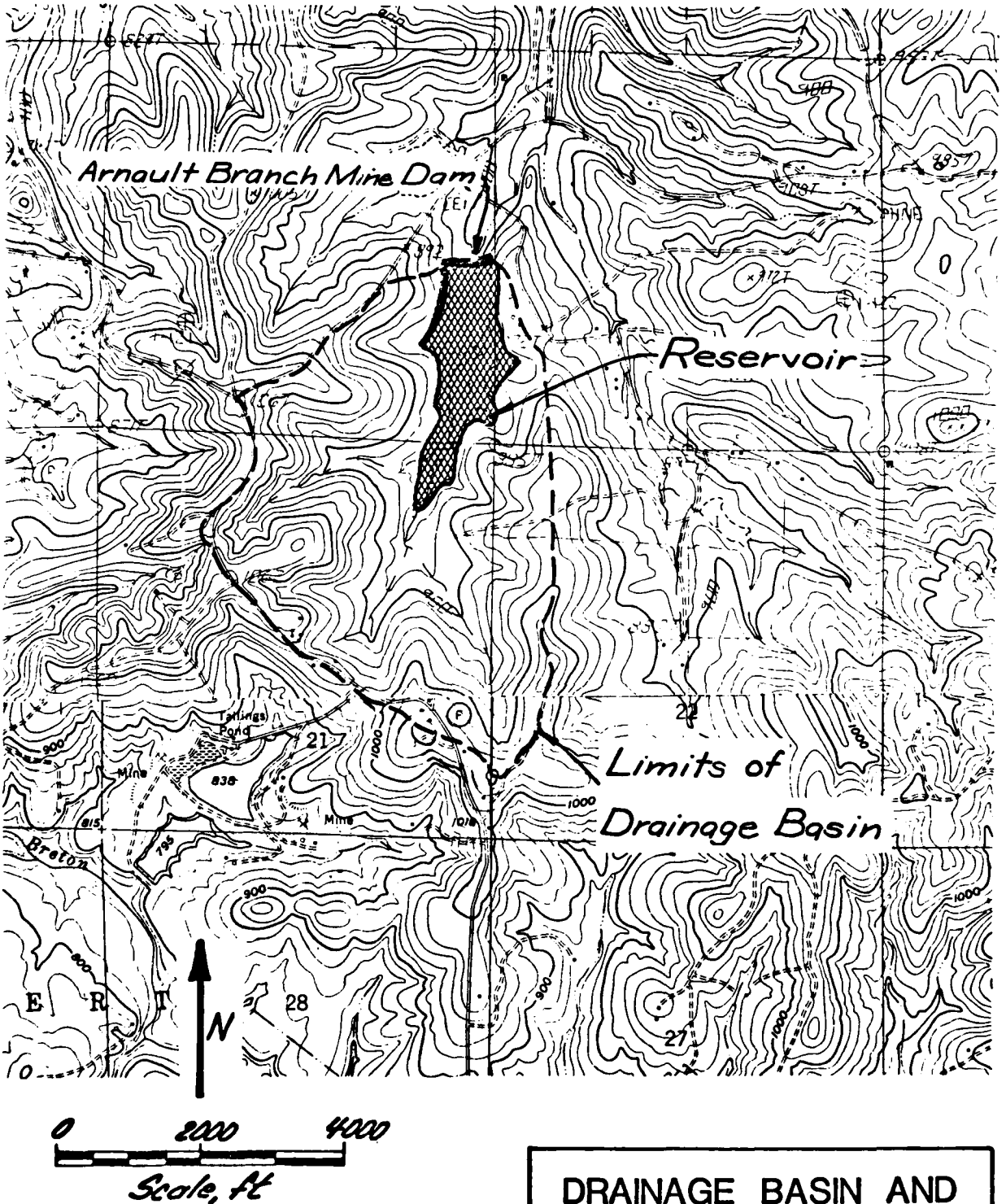
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.



SITE LOCATION MAP

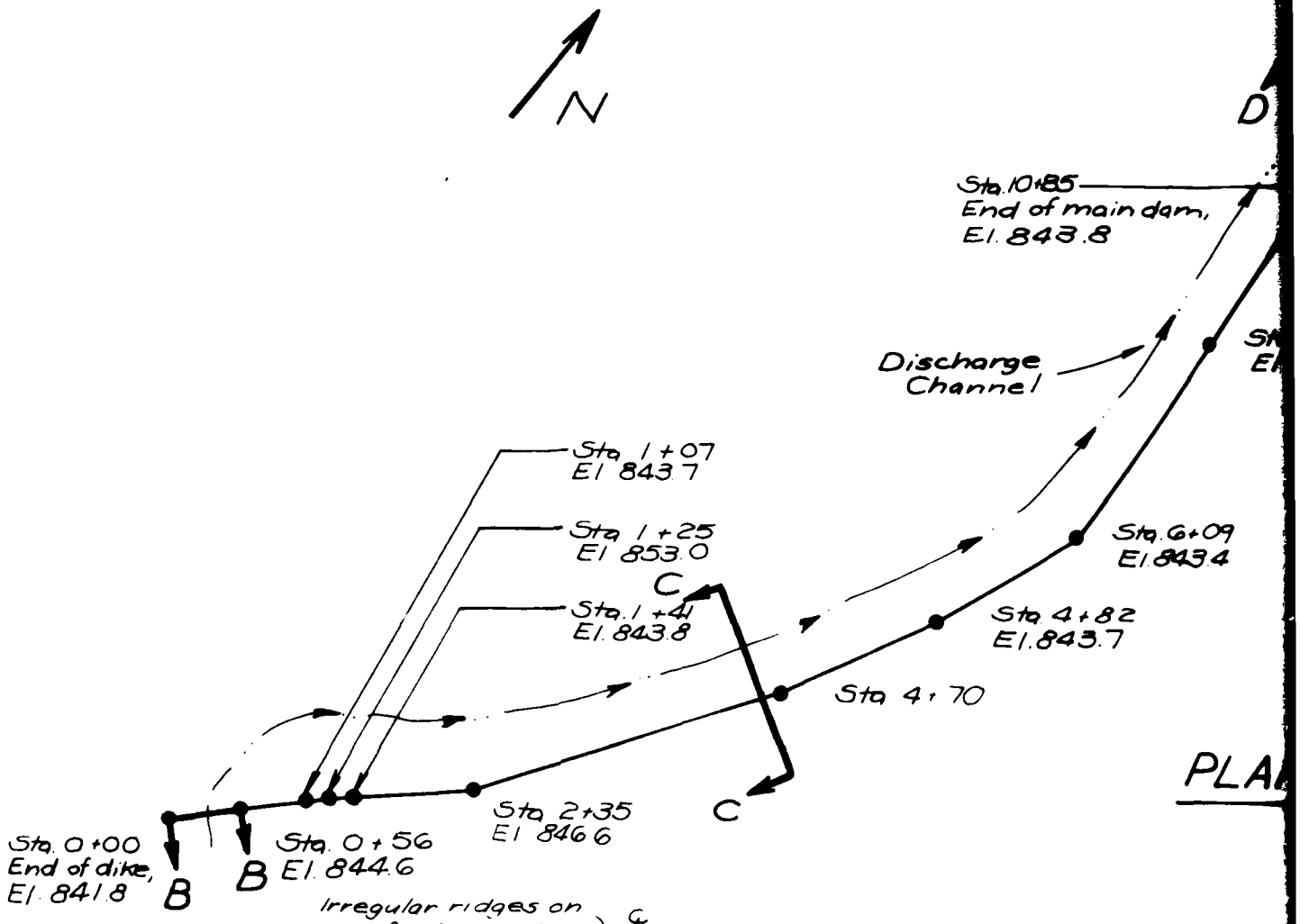
ARNAULT BRANCH MINE DAM

MO 30716 | Fig. 1

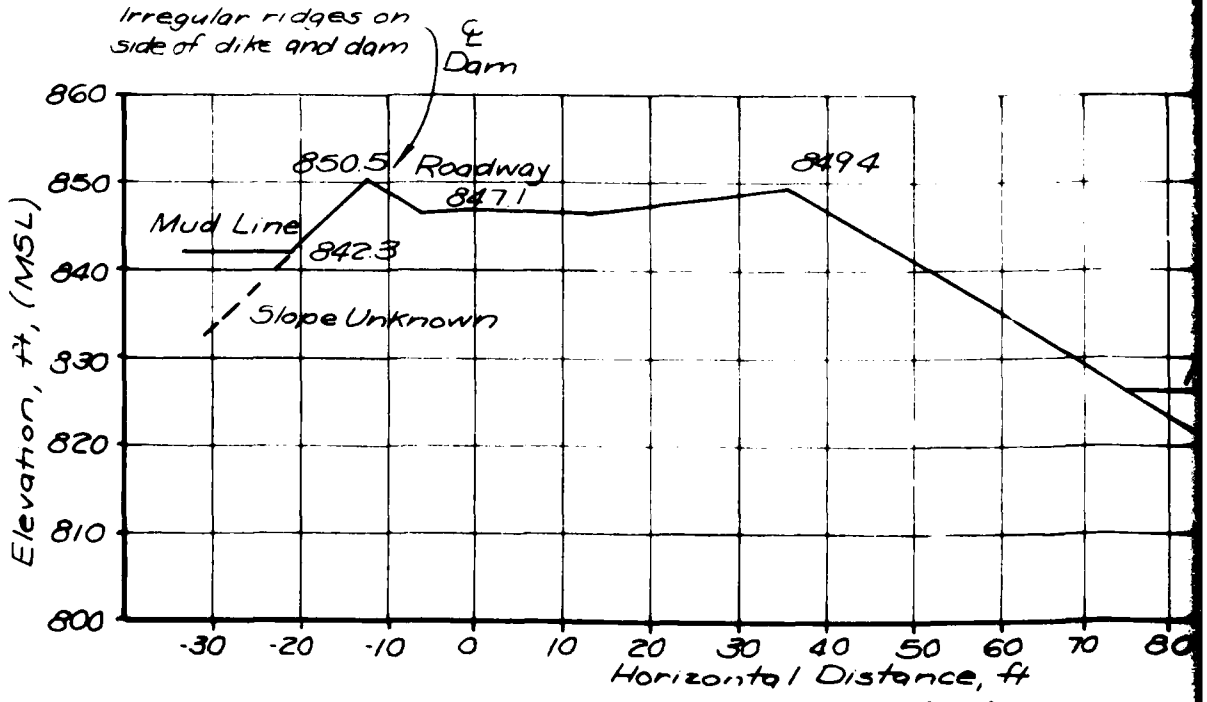


Topography from U.S.G.S. Richwoods SE and Potosi 7½ minute quadrangle map.

DRAINAGE BASIN AND SITE TOPOGRAPHY	
ARNAULT BRANCH MINE DAM	
MO 30716	Fig. 2

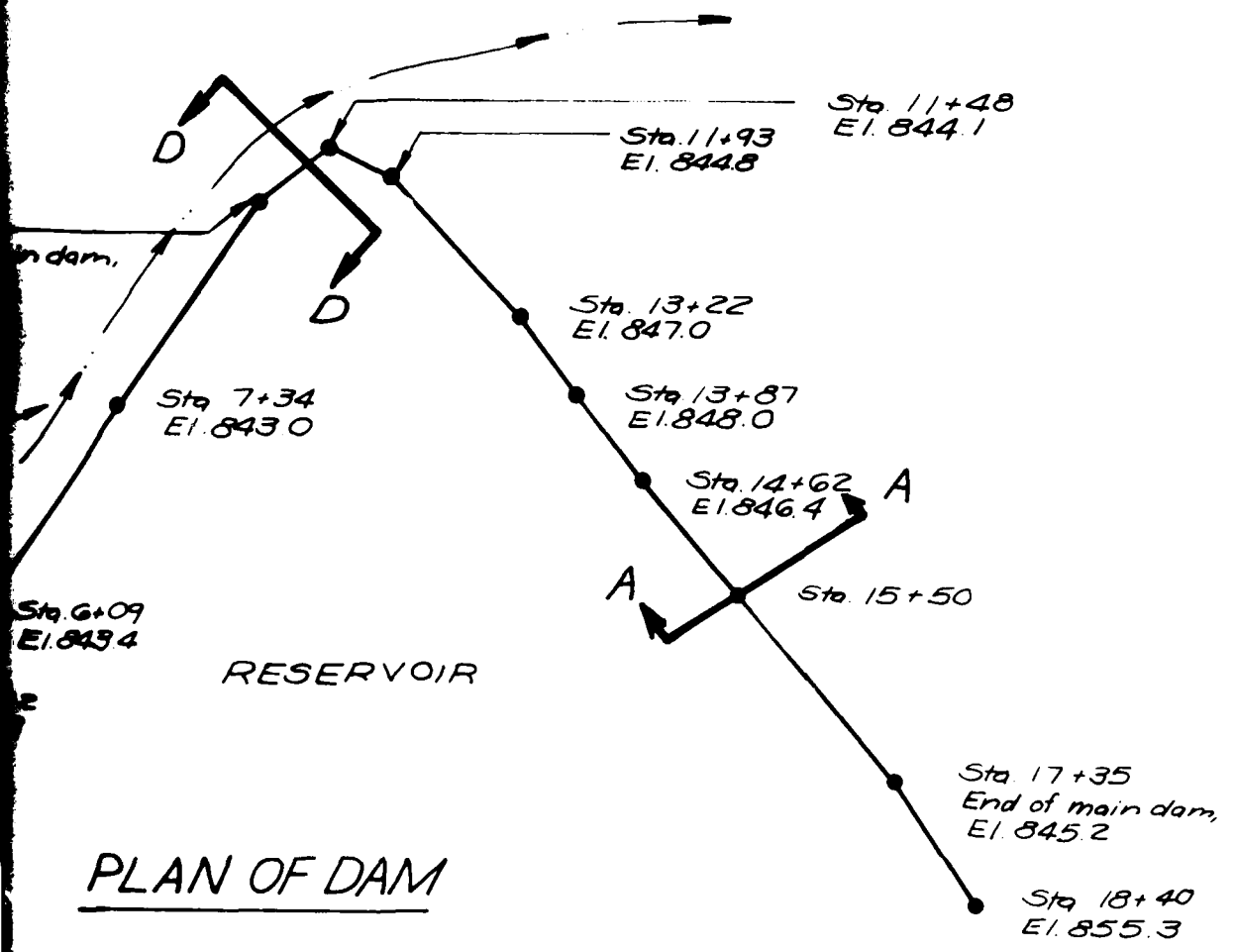


PLA

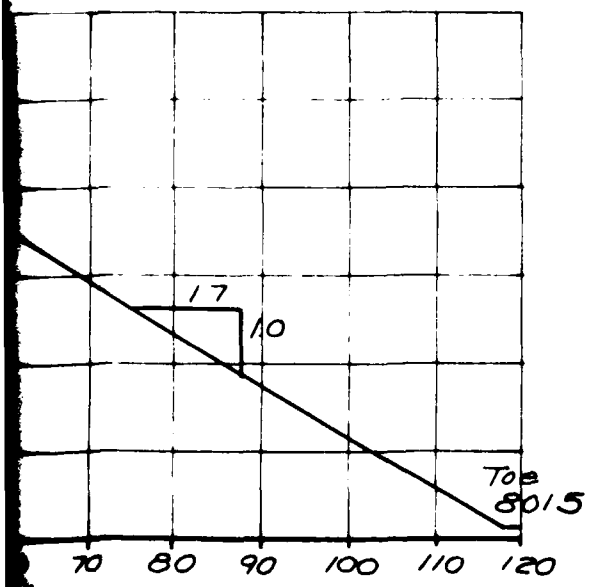


SECTION A-A

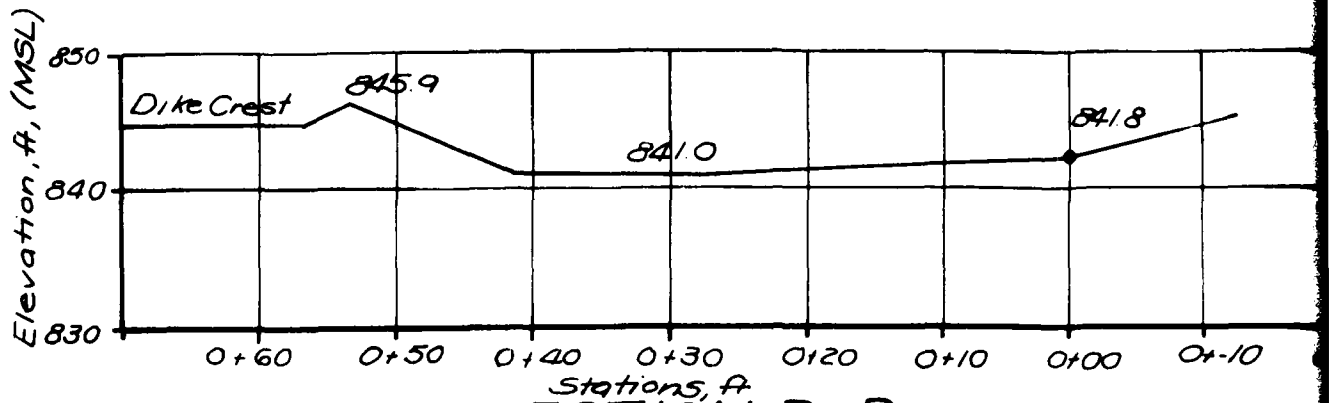
Maximum Dam Section



PLAN OF DAM

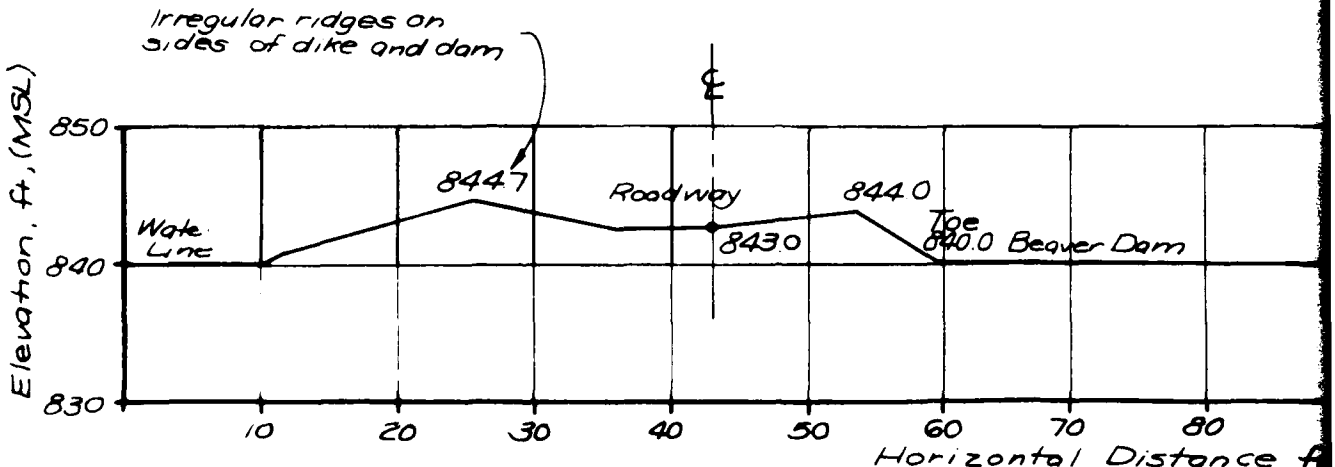


PLAN OF DAM AND MAXIMUM SECTION	
ARNAULT BRANCH MINE DAM	
MO 30716	Fig. 3 - A



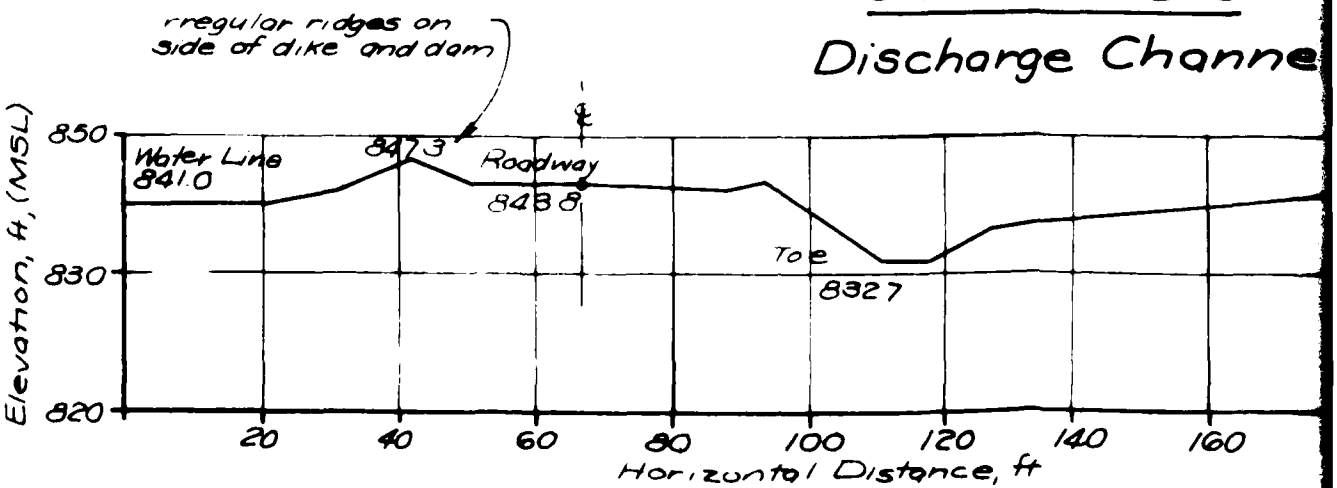
SECTION B-B

Spillway



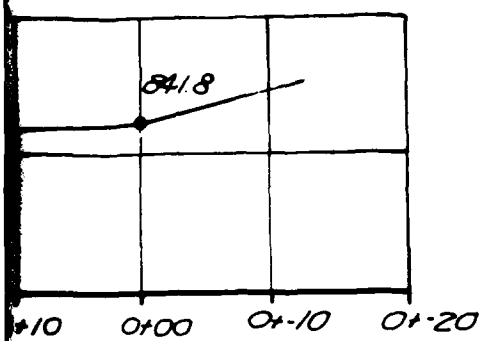
SECTION C-C

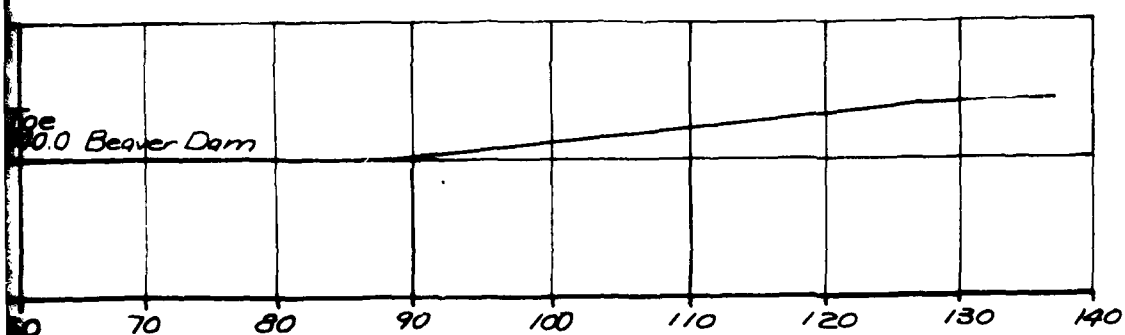
Discharge Channe



SECTION D-D

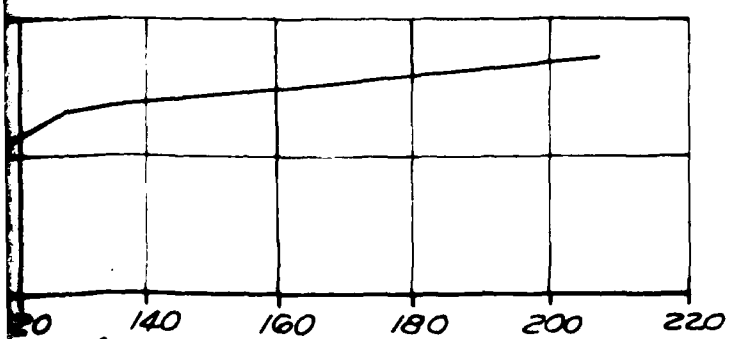
Discharge Channel





CTION C-C

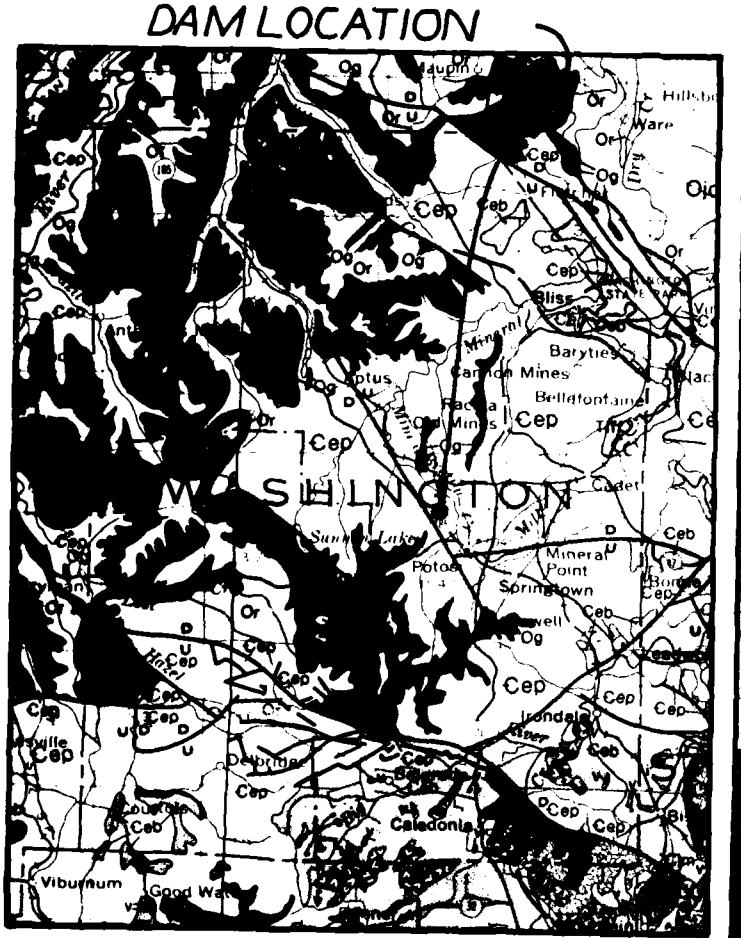
harge Channel



D-D

annel

SECTIONS OF SPILLWAY AND DISCHARGE CHANNEL	
ARNAULT BRANCH MINE DAM	
MO 30716	Fig. 3 - B



N

0 10 20

Scale, mile

Legend

- Or — Roubidoux Formation; Gasconade Dolomite, Gunter Sandstone Member
- Cep — Eminence Dolomite; Potosi Dolomite
- Ceb — Derby-Doerun Dolomite; Davis Formation; Bonneterre Formation, Whetstone Creek Member, Sullivan Siltstone Member
- Reagan Sandstone (subsurface, western Missouri)
- Lamotte Sandstone
- Diabase (dikes and sills)
- St. Francois Mountains Intrusive Suite
- St. Francois Mountains Volcanic Supergroup

REGIONAL GEOLOGIC MAP

ARNAULT BRANCH MINE DAM

MO 30716 | **Fig. 4**

APPENDIX A

Photographs

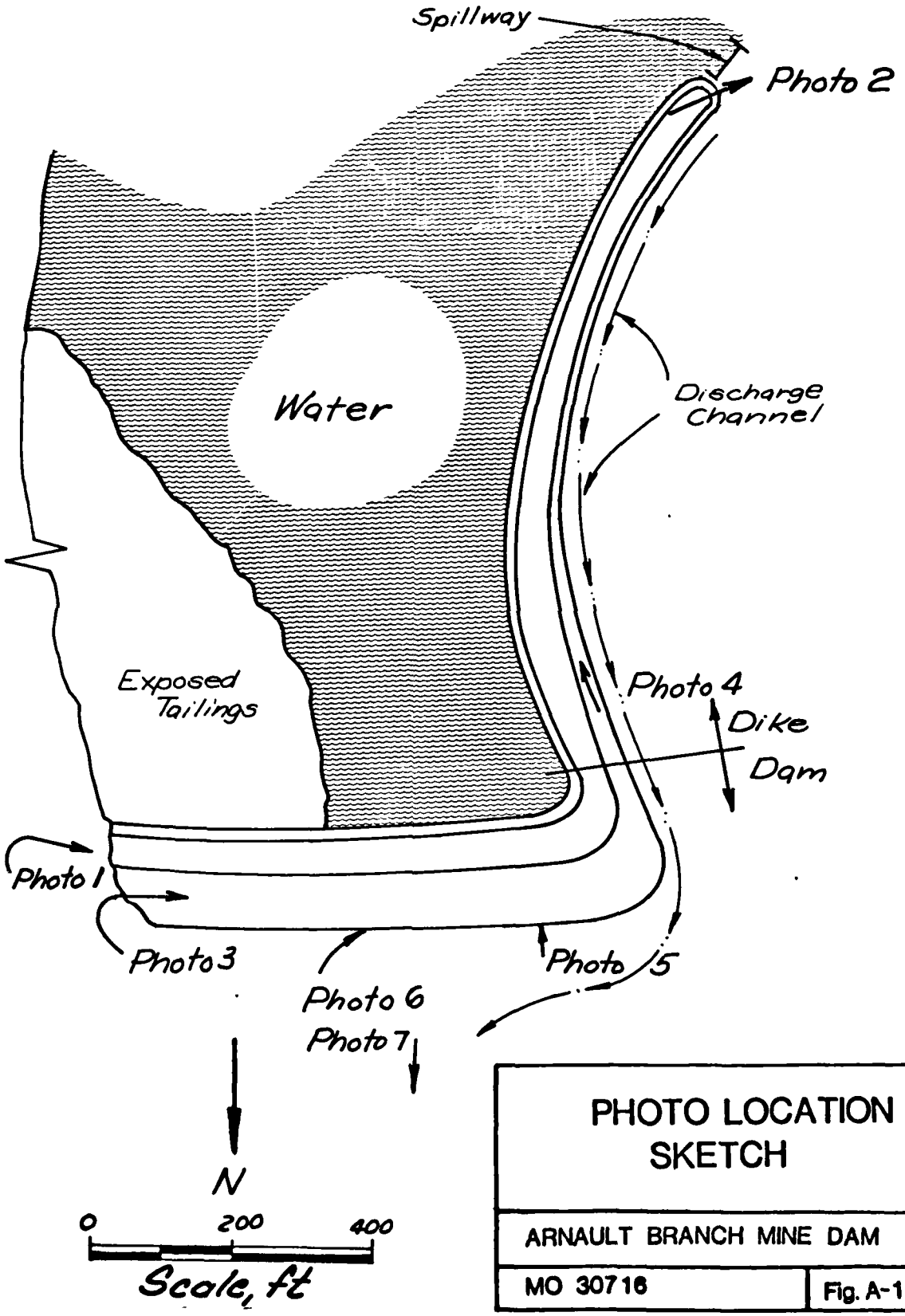


PHOTO LOCATION SKETCH

ARNAULT BRANCH MINE DAM

MO 30716 | Fig. A-1

1. View along crest from east abutment.

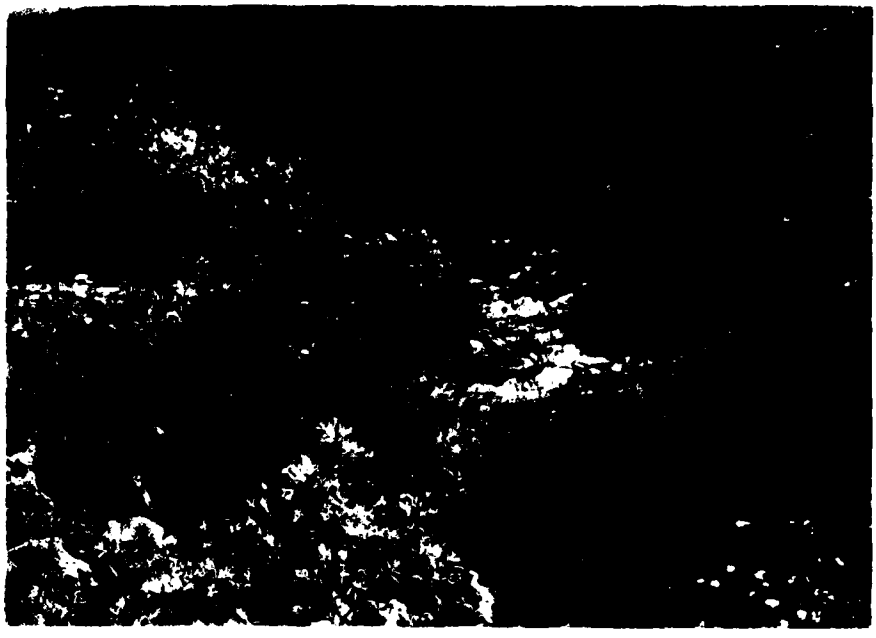
2. Spillway area located at south end of dike.

3. Downstream slope from east abutment. Unevenness due to uncontrolled construction. (See Section 3.1.b)

4. Discharge channel along side dike. Looking upstream.

5. Clear seepage from toe of dam of about 2-4 gal/min. Located near west end of dam.

6. Clear seepage from toe of dam ponding in low area. Exit is in heavy growth in background. Note rock outcrop.



7. View of downstream channel looking downstream.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B
Hydraulic/Hydrologic Data and Analyses

B.1 Procedures

a. General. The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. The inflow hydrographs were developed for various precipitation events by applying them to a synthetic unit hydrograph. The inflow hydrographs were subsequently routed through the reservoir and appurtenant structures by the modified Puls reservoir routing option.

b. Precipitation events. The Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The total rainfall and corresponding distributions for the 1 and 10 percent probability events were provided by the St Louis District, Corps of Engineers. The Probable Maximum Precipitation was determined from regional curves prepared by the US Weather Bureau (Hydrometeorological Report Number 33, 1956).

c. Unit hydrograph. The Soil Conservation Services (SCS) Dimensionless Unit Hydrograph method (National Engineering Handbook, Section 4, Hydrology, 1971) was used in the analyses. This method was selected because of its simplicity, applicability to drainage areas less than 10 mi^2, and its easy availability within the HEC-1 computer program.

The watershed lag time was computed using the SCS "curve number method" by an empirical relationship as follows:

$$L = \frac{\ell^{0.8}(s+1)^{0.7}}{1900\, Y^{0.5}} \qquad \text{(Equation 15-4)}$$

where: L = lag in hours
ℓ = hydraulic length of the watershed in feet
$s = \frac{1000}{CN} - 10$ where CN = hydrologic soil curve number
Y = average watershed land slope in percent

This empirical relationship accounts for the soil cover, average watershed slope and hydraulic length.

With the lag time thus computed, another empirical relationship is used to compute the time of concentration as follows:

$$T_c = \frac{L}{0.6} \qquad \text{(Equation 15-3)}$$

where: T_c = time of concentration in hours

L = lag in hours.

Subsequent to the computation of the time of concentration, the unit hydrograph duration was estimated utilizing the following relationship:

$$\Delta D = 0.133 T_c \qquad \text{(Equation 16-12)}$$

where: ΔD = duration of unit excess rainfall
T_c = time of concentration in hours.

The final interval was selected to provide at least three discharge ordinates prior to the peak discharge ordinate of the unit hydrograph. For this dam, a time interval of 10 minutes was used.

d. Infiltration losses. The infiltration losses were computed by the HEC-1 computer program internally using the SCS curve number method. The curve numbers were established taking into consideration the variables of: (a) antecedent moisture condition, (b) hydrologic soil group classification, (c) degree of development, (d) vegetative cover and (e) present land usage in the watershed.

Antecedent moisture condition III (AMC III) was used for the PMF events and AMC II was used for the 1 and 10 percent probability events, in accordance with the guidelines. The remaining variables are defined in the SCS procedure and judgements in their selection were made on the basis of visual field inspection.

e. Starting elevations. Reservoir starting water surface elevations for this dam were set as follows:

(1) 1 and 10 percent probability events - spillway crest elevation

(2) Probable Maximum Storm - spillway crest elevation

f. Spillway Rating Curve. The HEC-2 computer program was used to compute the spillway rating curve using discharge channel cross sections and conveyance characteristics.

B.2 Pertinent Data

a. Drainage area. 0.85 mi^2

b. Storm duration. A unit hydrograph was developed by the SCS method option of HEC-1 program. The design storm of 48 hours duration was divided into 10 minute intervals in order to develop the inflow hydrograph.

c. Lag time. 0.7 hrs

d. Hydrologic soil group. D

e. SCS curve numbers.

1. For PMF- AMC III - Curve Number 91
2. For 1 and 10 percent probability-of-occurrence events - AMC II - Curve Number 79

f. Storage. Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Richwoods SE 7.5-minute quadrangle map. The data were entered on the $A and $E cards so that the HEC-1 program could compute storage volumes.

g. Outflow over dam crest. As the profile of the dam crest is irregular, flow over the crest was computed according to the "Flow Over Non-Level Dam Crest" supplement to the HEC-1 User's Manual. The crest length-elevation data and hydraulic constants were entered on the $D, $L, and $V cards.

h. Outflow capacity. The spillway rating curve was developed from the cross-section data of the spillway and the downstream channel, using the HEC-2 back water program. The results of the above were entered on the Y-4 and Y-5 cards of the HEC-1 program.

i. Reservoir elevations. For the 50 and 100 percent of the PMF events, the starting reservoir elevation was 840.1 ft, the spillway crest elevation. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was 840.1 ft, the spillway crest elevation.

B.3 Results

The results of the analyses as well as the input values to the HEC-1 program follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 output are available in the project files.

```
**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 90
**********
    1                 A1       DAM NO. 30716 - ARNARTT BRANCH MINE DAM
    2                 A2       WOODWARD CLYDE CONSULTANTS, HOUSTON  79CH0009
    3                 A3       PROBABLE MAXIMUM FLOOD(PMF) RATIO FLOOD ANALYSIS
    4                 B    288        0       10       -0       -0       -0       -0       -0       -0       -0
    5                 B1     5
    6                 J     1         4        1
    7                 J1   .25      .50      .75      1.0
    8                 K     0     LAKE                                                  1
    9                 K1       INFLOW HYDROGRAPH TO ARNARTT BRANCH MINE DAM
   10                 M     1        2      .85                        1                                  1
   11                 P     0      26.    102.     120.     130.     140.
   12                 T                                                                -1       -91               .07
   13                 W2              .7
   14                 X    -2     -.05        5
   15                 K     1     DAM                                                   1
   16                 K1       ROUTING THROUGH LAKE AND OVERTOPPING ANALYSIS
   17                 V                                          1        1
   18                 Y1    1                                                        -840.1      -1
   19                 Y4 840.1   841.4    842.3    842.9    844.3    845.1    846.1
   20                 Y5    0.     10.      50.     100.0    300.0    500.0    800.0
   21                 SA  10.9     33.9     80.0
   22                 SE  820.     840.     860.
   23                 SS 840.1
   24                 SD  843.      2.5      1.5
   25                 SL    0.     750.    1070.    1340.    1550.    1680.    1700.
   26                 SV  843.     844.     845.     846.     847.     848.     849.
   27                 K    99
```

```
**********************************
*FLOOD HYDROGRAPH PACKAGE (HEC-1)
*DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
**********************************

RUN  DATE: 22 JUL 83
     TIME: 13.29.28
```

DAM NO. 30716 - ARNARTT BRANCH MINE DAM
WOODWARD CLYDE CONSULTANTS, HOUSTON 79CH009
PROBABLE MAXIMUM FLOW(PMF) RATIO FLOOD ANALYSIS

JOB SPECIFICATION

NO	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
288	0	10	-0	-0	-0	-0	-0	-0	-0

JOPER	NWT	LROPT	TRACE
5	-0	-0	-0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 4 LRTIO= 1

RTIOS= .25 .50 .75 1.00

********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

INFLOW HYDROGRAPH TO ARNARTT BRANCH MINE DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
LAKE	0	-0	-0	-0	-0	1	-0	-0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	2	.85	-0.	.85	1.00	-0.	-0	1	-0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.	26.00	102.00	120.00	130.00	140.00	-0.	-0.

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
-0	-0.	-0.	1.00	-0.	-0.	1.00	-1.00	-91.00	-0.	.07

CURVE NO = -91.00 HETNESS = -1.00 EFFECT CN = 91.00

UNIT HYDROGRAPH DATA
TC= -0. LAG= .70

RECESSION DATA
STRTQ= -2.00 QRCSN= -.05 RTIOR= 5.00

Output Summary
Various PMF Events
Arnault Branch Mine Dam
MO ID No. 30716

CURVE NO = -91.00 WETNESS = -1.00 EFFECT CN = 91.00

UNIT HYDROGRAPH DATA
TC= -0. LAG= .70

RECESSION DATA
STRTQ= -2.00 QRCSN= -.05 RTIOR= 5.00

UNIT HYDROGRAPH 23 END OF PERIOD ORDINATES, TC= -0. HOURS, LAG= .70 VOL= 1.00

98.	194.	378.	504.	521.	460.	367.	240.	169.	122.		
86.	61.	43.	30.	21.	15.	11.	8.	6.	4.		
3.	2.	1.									

0 END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.10	1	.00	.00	.00	1.	1.02	.10	145	.03	.03	.00	11.
1.01	.20	2	.00	.00	.00	1.	1.02	.20	146	.03	.03	.00	16.
1.01	.30	3	.00	.00	.00	1.	1.02	.30	147	.03	.03	.00	25.
1.01	.40	4	.00	.00	.00	1.	1.02	.40	148	.03	.03	.00	37.
1.01	.50	5	.00	.00	.00	1.	1.02	.50	149	.03	.03	.00	49.
1.01	1.00	6	.00	.00	.00	1.	1.02	1.00	150	.03	.03	.00	60.
1.01	1.10	7	.00	.00	.00	1.	1.02	1.10	151	.03	.03	.00	68.
1.01	1.20	8	.00	.00	.00	1.	1.02	1.20	152	.03	.03	.00	74.
1.01	1.30	9	.00	.00	.00	1.	1.02	1.30	153	.03	.03	.00	78.
1.01	1.40	10	.00	.00	.00	1.	1.02	1.40	154	.03	.03	.00	81.
1.01	1.50	11	.00	.00	.00	1.	1.02	1.50	155	.03	.03	.00	83.
1.01	2.00	12	.00	.00	.00	1.	1.02	2.00	156	.03	.03	.00	85.
1.01	2.10	13	.00	.00	.00	1.	1.02	2.10	157	.03	.03	.00	86.
1.01	2.20	14	.00	.00	.00	1.	1.02	2.20	158	.03	.03	.00	87.
1.01	2.30	15	.00	.00	.00	1.	1.02	2.30	159	.03	.03	.00	87.
1.01	2.40	16	.00	.00	.00	1.	1.02	2.40	160	.03	.03	.00	88.
1.01	2.50	17	.00	.00	.00	1.	1.02	2.50	161	.03	.03	.00	88.
1.01	3.00	18	.00	.00	.00	1.	1.02	3.00	162	.03	.03	.00	89.
1.01	3.10	19	.00	.00	.00	1.	1.02	3.10	163	.03	.03	.00	89.
1.01	3.20	20	.00	.00	.00	1.	1.02	3.20	164	.03	.03	.00	89.
1.01	3.30	21	.00	.00	.00	1.	1.02	3.30	165	.03	.03	.00	89.
1.01	3.40	22	.00	.00	.00	1.	1.02	3.40	166	.03	.03	.00	89.
1.01	3.50	23	.00	.00	.00	1.	1.02	3.50	167	.03	.03	.00	89.
1.01	4.00	24	.00	.00	.00	1.	1.02	4.00	168	.03	.03	.00	89.
1.01	4.10	25	.00	.00	.00	1.	1.02	4.10	169	.03	.03	.00	89.
1.01	4.20	26	.00	.00	.00	1.	1.02	4.20	170	.03	.03	.00	90.
1.01	4.30	27	.00	.00	.00	1.	1.02	4.30	171	.03	.03	.00	90.
1.01	4.40	28	.00	.00	.00	1.	1.02	4.40	172	.03	.03	.00	90.
1.01	4.50	29	.00	.00	.00	1.	1.02	4.50	173	.03	.03	.00	90.
1.01	5.00	30	.00	.00	.00	1.	1.02	5.00	174	.03	.03	.00	90.
1.01	5.10	31	.00	.00	.00	1.	1.02	5.10	175	.03	.03	.00	90.
1.01	5.20	32	.00	.00	.00	1.	1.02	5.20	176	.03	.03	.00	90.
1.01	5.30	33	.00	.00	.00	1.	1.02	5.30	177	.03	.03	.00	90.
1.01	5.40	34	.00	.00	.00	1.	1.02	5.40	178	.03	.03	.00	90.
1.01	5.50	35	.00	.00	.00	1.	1.02	5.50	179	.03	.03	.00	90.
1.01	6.00	36	.00	.00	.00	1.	1.02	6.00	180	.03	.03	.00	90.
1.01	6.10	37	.01	.00	.01	1.	1.02	6.10	181	.13	.12	.01	96.
1.01	6.20	38	.01	.00	.01	1.	1.02	6.20	182	.13	.12	.01	114.
1.01	6.30	39	.01	.00	.01	1.	1.02	6.30	183	.13	.12	.01	151.
1.01	6.40	40	.01	.00	.01	1.	1.02	6.40	184	.13	.13	.00	199.
1.01	6.50	41	.01	.00	.01	1.	1.02	6.50	185	.13	.13	.00	250.
1.01	7.00	42	.01	.00	.01	2.	1.02	7.00	186	.13	.13	.00	295.
1.01	7.10	43	.01	.00	.01	2.	1.02	7.10	187	.13	.13	.00	331.
1.01	7.20	44	.01	.00	.01	2.	1.02	7.20	188	.13	.13	.00	355.
1.01	7.30	45	.01	.00	.01	2.	1.02	7.30	189	.13	.13	.00	372.
1.01	7.40	46	.01	.00	.01								

Output Summary
Various PMF Events
Arnault Branch Mine Dam
MO ID No. 30716

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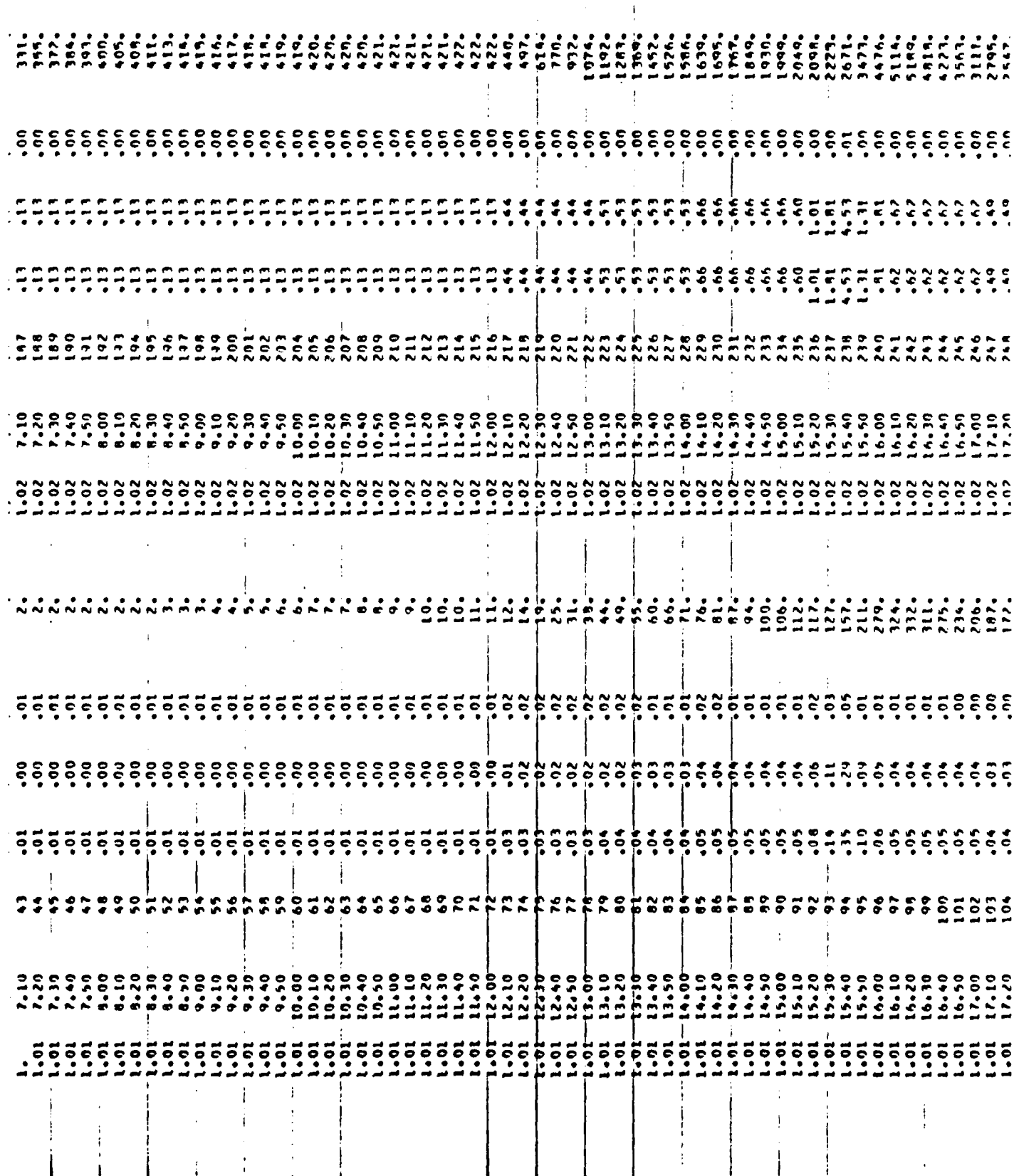

Output Summary
Various PMF Events
Arnault Branch Mine Dam
MO ID No. 30716

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1.01	16.30	99	.05	.04	.01	311.	1.02	16.30	243	.62	.62	.00	4818.
1.01	16.40	100	.05	.04	.01	275.	1.02	16.40	244	.62	.62	.00	4223.
1.01	16.50	101	.05	.04	.00	234.	1.02	16.50	245	.62	.62	.00	3563.
1.01	17.00	102	.05	.04	.00	206.	1.02	17.00	246	.62	.62	.00	3111.
1.01	17.10	103	.04	.03	.00	187.	1.02	17.10	247	.49	.49	.00	2795.
1.01	17.20	104	.04	.03	.00	172.	1.02	17.20	248	.49	.49	.00	2547.
1.01	17.30	105	.04	.03	.00	158.	1.02	17.30	249	.49	.49	.00	2337.
1.01	17.40	106	.04	.03	.00	147.	1.02	17.40	250	.49	.49	.00	2157.
1.01	17.50	107	.04	.03	.00	139.	1.02	17.50	251	.49	.49	.00	2007.
1.01	18.00	108	.04	.03	.00	130.	1.02	18.00	252	.49	.49	.00	1890.
1.01	18.10	109	.00	.00	.00	123.	1.02	18.10	253	.04	.04	.00	1777.
1.01	18.20	110	.00	.00	.00	114.	1.02	18.20	254	.04	.04	.00	1636.
1.01	18.30	111	.00	.00	.00	99.	1.02	18.30	255	.04	.04	.00	1426.
1.01	18.40	112	.00	.00	.00	82.	1.02	18.40	256	.04	.04	.00	1174.
1.01	18.50	113	.00	.00	.00	64.	1.02	18.50	257	.04	.04	.00	922.
1.01	19.00	114	.00	.00	.00	49.	1.02	19.00	258	.04	.04	.00	703.
1.01	19.10	115	.00	.00	.00	37.	1.02	19.10	259	.04	.04	.00	529.
1.01	19.20	116	.00	.00	.00	29.	1.02	19.20	260	.04	.04	.00	413.
1.01	19.30	117	.00	.00	.00	23.	1.02	19.30	261	.04	.04	.00	332.
1.01	19.40	118	.00	.00	.00	19.	1.02	19.40	262	.04	.04	.00	275.
1.01	19.50	119	.00	.00	.00	17.	1.02	19.50	263	.04	.04	.00	236.
1.01	20.00	120	.00	.00	.00	15.	1.02	20.00	264	.04	.04	.00	207.
1.01	20.10	121	.00	.00	.00	13.	1.02	20.10	265	.04	.04	.00	188.
1.01	20.20	122	.00	.00	.00	12.	1.02	20.20	266	.04	.04	.00	174.
1.01	20.30	123	.00	.00	.00	12.	1.02	20.30	267	.04	.04	.00	164.
1.01	20.40	124	.00	.00	.00	11.	1.02	20.40	268	.04	.04	.00	157.
1.01	20.50	125	.00	.00	.00	11.	1.02	20.50	269	.04	.04	.00	152.
1.01	21.00	126	.00	.00	.00	11.	1.02	21.00	270	.04	.04	.00	149.
1.01	21.10	127	.00	.00	.00	10.	1.02	21.10	271	.04	.04	.00	147.
1.01	21.20	128	.00	.00	.00	10.	1.02	21.20	272	.04	.04	.00	145.
1.01	21.30	129	.00	.00	.00	10.	1.02	21.30	273	.04	.04	.00	143.
1.01	21.40	130	.00	.00	.00	10.	1.02	21.40	274	.04	.04	.00	143.
1.01	21.50	131	.00	.00	.00	10.	1.02	21.50	275	.04	.04	.00	142.
1.01	22.00	132	.00	.00	.00	10.	1.02	22.00	276	.04	.04	.00	142.
1.01	22.10	133	.00	.00	.00	10.	1.02	22.10	277	.04	.04	.00	142.
1.01	22.20	134	.00	.00	.00	10.	1.02	22.20	278	.04	.04	.00	142.
1.01	22.30	135	.00	.00	.00	10.	1.02	22.30	279	.04	.04	.00	142.
1.01	22.40	136	.00	.00	.00	10.	1.02	22.40	280	.04	.04	.00	142.
1.01	22.50	137	.00	.00	.00	10.	1.02	22.50	281	.04	.04	.00	142.
1.01	23.00	138	.00	.00	.00	10.	1.02	23.00	282	.04	.04	.00	142.
1.01	23.10	139	.00	.00	.00	10.	1.02	23.10	283	.04	.04	.00	142.
1.01	23.20	140	.00	.00	.00	10.	1.02	23.20	284	.04	.04	.00	142.
1.01	23.30	141	.00	.00	.00	10.	1.02	23.30	285	.04	.04	.00	142.
1.01	23.40	142	.00	.00	.00	10.	1.02	23.40	286	.04	.04	.00	142.
1.01	23.50	143	.00	.00	.00	10.	1.02	23.50	287	.04	.04	.00	142.
1.02	0.	144	.00	.00	.00	10.	1.03	0.	288	.04	.04	.00	142.
									SUM	36.40	35.32	1.08	115477.
										(925.)(	897.)(	27.)(	3269.94)

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1	RATIO 2	RATIO 3	RATIO 4
				.25	.50	.75	1.00
HYDROGRAPH AT	LAKE	.89	1	1297.	2595.	3892.	5189.
		(2.20)	(	36.74)(	73.47)(	110.21)(	146.94)(
ROUTED TO	DAM	.89	1	1202.	2500.	3801.	5111.
		(2.20)	(	34.05)(	70.78)(	107.64)(	144.72)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	840.10	840.10	843.00
STORAGE	430.	430.	537.
OUTFLOW	0.	0.	114.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.25	844.04	1.04	579.	1202.	6.67	40.50	0.
.50	844.44	1.44	596.	2500.	10.83	40.50	0.
.75	844.74	1.74	609.	3801.	15.17	40.33	0.
1.00	845.00	2.00	620.	5111.	16.33	40.33	0.

Output Summary
Various PMF Events
Arnault Branch Mine Dam
MO ID No. 30716

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO 1	RATIO 2	RATIO 3	RATIO 4	RATIO 5	RATIO 6	RATIO 7	RATIO 8
				.05	.06	.07	.08	.09	.10	.11	.12
HYDROGRAPH AT	LAKE	.85	1	259.	311.	363.	415.	467.	519.	571.	623.
	(	2.20)	(	7.35)(	8.82)(	10.29)(	11.76)(	13.22)(	14.69)(	16.16)(	17.63)(
ROUTED TO	DAM	.85	1	36.	47.	68.	89.	115.	155.	209.	277.
	(	2.20)	(	.96)(	1.34)(	1.93)(	2.52)(	3.24)(	4.38)(	5.93)(	7.74)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	840.10	840.10	843.00
	STORAGE	430.	430.	537.
	OUTFLOW	0.	0.	114.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.05	841.94	0.	496.	34.	0.	43.00	0.
.06	842.24	0.	507.	47.	0.	43.00	0.
.07	842.52	0.	518.	68.	0.	42.83	0.
.08	842.77	0.	528.	89.	0.	42.67	0.
.09	843.00	.00	537.	115.	.33	42.67	0.
.10	843.19	.19	544.	155.	2.67	42.33	0.
.11	843.32	.32	549.	209.	3.33	42.00	0.
.12	843.42	.42	554.	273.	3.83	41.50	0.

Output Summary
Equivalent PMF Analyses
Arnault Branch Mine Dam
MO ID No. 30716
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